Narrow Gap Improved Electroslag Welding of Bridge Steels

NGI-ESW Process

The narrow gap improved electroslag welding (NGI-ESW) process is an optimized version of conventional consumable guide electroslag welding to meet the current toughness requirements of Zone 2 bridges. Compared to conventional electroslag welding, the NGI-ESW process is characterized by: (a) improved CVN toughness of the weld metal and heat-affected zone (HAZ), (b) excellent fatigue strength, and (c) increased productivity. The NGI-ESW process can be used for joining A709 grades 250, 345 and 345W for typical thicknesses of 50 mm or more.

Background

Previous research has shown that the conventional electroslag welding process was incapable of consistently producing the required toughness values in weld metal and particularly in the HAZ for A709 grades 250 and 345, and 345W steels. FHWA supported research, which is described in FHWA Report No. FHWA/RD-97/026, resulted in the NGI-ESW process. NGI-ESW was designed to reduce heat input in order to increase HAZ toughness. NGI-ESW has been shown to meet the new more-stringent toughness requirements of non-fracture critical tension members on bridges in Zone 2.

Distinguishing Features of NGI-ESW

Electroslag welding is an arcless process. NGI-ESW is characterized by a narrow gap of only 19mm and a tubular metal-powder-cored filler metal. Welding is achieved by resistance heating a molten conductive slag to a sufficiently high temperature to melt the electrode, consumable guide, and faying surfaces of the base metal. Filler metal is added in the form of a 2.4mm diameter tubular metal-cored wire. The lighter slag pool floats above the dense weld metal pool. Both molten pools are supported by water-cooled copper “shoes”. The process is used for welding thick plate in a single pass. Unlike all other welding processes specified by the Bridge Welding Code, electroslag welding of A709 grades 250,345, and 345W bridge steels does not require preheating regardless of thickness. Thus, it is ideal for welding thick columns and plate girders end-to-end.

Advantages and Disadvantages of NGI-ESW

The outstanding advantage of the NGI-ESW process is its cost-effectiveness, which increases with increasing thickness. Multi-pass processes such as submerged arc welding provide excellent mechanical properties, however they are also extremely labor-intensive and time-consuming. In addition, NGI-ESW requires little edge preparation and no costly preheating. The primary disadvantage to NGI-ESW process is that it must be performed in the vertical-up position. As a result, there is a practical limit to the maximum length of weld that can be made which is about 4m.

Consumables used in NGI-ESW

NGI-ESW requires three primary consumables: filler metal, consumable guide, and flux. The filler metal is a 2.4mm diameter tubular metal-powder-cored wire, which contains key alloying ingredients to promote high toughness and excellent soundness. Based on laboratory testing, the recommended electrode composition is nominally: Fe- 0.03 C (max)-1.2Mn-3Ni-0.35Mo-0.02Ti. Since the weld admixture contains less than 50% filler metal, the composition of filler metal is designed to utilize the compositions of A709 grades 250, 345, and 345W base plates. The tubular filler metal must have the AWS low-hydrogen designator of "H-4" for NGI-ESW.

Similarly, the consumable guide melts during welding and provides about 15% of the weld admixture. Therefore, the guide must have a compatible chemical composition and must be kept as clean and dry as the filler metal. The recommended guide composition is: Fe-0.06C(max)-1Mn(max).

Flux must be dry and free of moisture and other contamination, because the resulting slag layer may transmit contaminants into the molten weld metal. Only fused fluxes must be used for NGI-ESW. Prior to welding by NGI-ESW, the flux must be baked to prevent hydrogen contamination of the weld.

When Should NGI-ESW be Used

NGI-ESW process can provide satisfactory welded butt joints and transition joints for non-fracture critical applications. Although it is possible to weld plates as thin as 25mm, NGI-ESW is best suited for thicknesses of 50mm and greater in order to achieve better economy than any other welding process permitted by the Bridge Welding Code. Thick-to-thin joints as thin as 50mm-to-32mm (2in-to-1 ¼in) are routinely joined. Thicker transition joints are also readily joined.

Non-Fracture Critical Only

NGI-ESW is permitted for tension and compression members for non-fracture critical applications in Zone 2.

Mechanical Properties

The NGI-ESW process is capable of producing the required tensile, CVN toughness, and bend properties for the weld metal as well as satisfactory CVN toughness for the heat-affected zone. Prior research has shown that electroslag weld metal and heat-affected zones have excellent resistance to fatigue loading.

Non-Destructive Evaluation by UT and RT

All welds deposited by NGI-ESW will be inspected by ultrasonic and radiographic inspection to ensure structural soundness.